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ANALYSIS OF BIOCONVERSION SYSTEMS AT THE VILLAGE LEVEL

PREFACE

This study was prepared for a conference sponsored by the World Hunger and Natural Resources Programme of the United Nations University, Guatemala City, November 1978.

In discussions over the course of a year on re-use of organic residues, ranging over the countries of the sub-continent and over all strata of society it was fairly obvious that a) there is no sense of urgency in taking scientific practice to the villages, and b) scientists feel lost without the paraphernalia of modern science and expensive logistical backups. In the case of organic residues, the practices were in existence long before the sciences were systematised. Unfortunately this fact is not self-evident to the scientific and bureaucratic conscience. Hence the lack of purpose.

What has been said here should be set against the following perspective : A recent study by the Madras Institute of Development Studies (C. T. Kurien : Director) has shown that there has been a direct exploitative suction of land and assets from the poorest to the richest in the rural areas of the state over the last 25 years. Contrary to lay opinion, people have not just procreated themselves out of possession. Proliferation, in fact, is the effect of exploitation and not the cause.

This study is about technology that can be tailored for self-reliance ; for use of village resources at the village level. It is a search for ways to stem the alarming advance of poverty and deprivation among the rural poor ; for a rational way to use residues. It would not have been possible without the support and enthusiasm of my colleagues : in particular, M. V. Murugappan, Venkataramani, Sebastian Thomas and Vasanth. Friends all over the country and in Pakistan, Bangla Desh, and Nepal have responded to enquiries. For their help, I am grateful.

Madras

November 1978.

C. V. Seshadri

ABSTRACT : An attempt has been made to evolve rational procedures for investment decisions on bioconversion systems at the rural level. Some quantitative comparisons are given based on data from this laboratory. Future developmental possibilities in bioconversion are indicated.

INTRODUCTION : The diversity of residue utilisation in rural communities is so great and its nature so non-quantitative that a complete analysis is a difficult task. In such a situation, choosing one method of utilising organic residues over another has to be based strictly on traditon and intution, rather than depending on rational procedures (if these can be found). There is therefore a necessity for evolving procedures to decide the best mode of residue utilisation. This article attempts to do this in the first part, as shown in Slide 1. In the second part some quantitative comparisions are made based on data obtained in this laboratory (referred to as M. C. R. C.). In the third part, some developmental possibilities are indicated for the future.

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01 Approach to Bioconversion Analysis

02 Some Results and Costs from Integrated Systems

03 Future Developmental Possibilities

Slide 01 Analysis of Bioconversion of Residues

Though an attempt has been made to obtain information from the South and East Asian regions, the background material is mainly based on Indian experience.

I. APPROACH TO BIOCONVERSION ANALYSIS: Barnett[1] and the companion articles in the same volume have provided an admirable framework for evaluation of alternate investment decisions in biogas systems. This reference should be required reading for decision makers in the rural energy area. The present study may be considered complementary since it looks at bioconversion in general. The analysis is restricted to bioconversion for energy, feed and possibly food.

Consider Slide 2. This slide is intended to demonstrate the alternative possibilities for using a common residue, i. e. straw. What criteria should be used by the rural people to derive the optimum benefit from the straw? As can be seen from the slide, the farmer has a number of choices; how does he decide whether to sell the straw in exchange for other goods, digest it for energy, or use it as fuel or feed directly. It is thus necessary to evolve some simple rules to enable him to make a decision. If self-reliance in energy and feed is the goal that is considered politically desirable, then the man who owns the straw should be clearly steered away from marketing it for alternate uses not leading to energy and feed.

Straw and Similar Residues :

(i) Building Material/Composites

(ii) Combustion

(iii) Feed to Animals

(iv) Ensilage and/or Storage

(v) Biogas

(vi) Any Alternate Bioconversion
(for example Termites, Mushrooms)

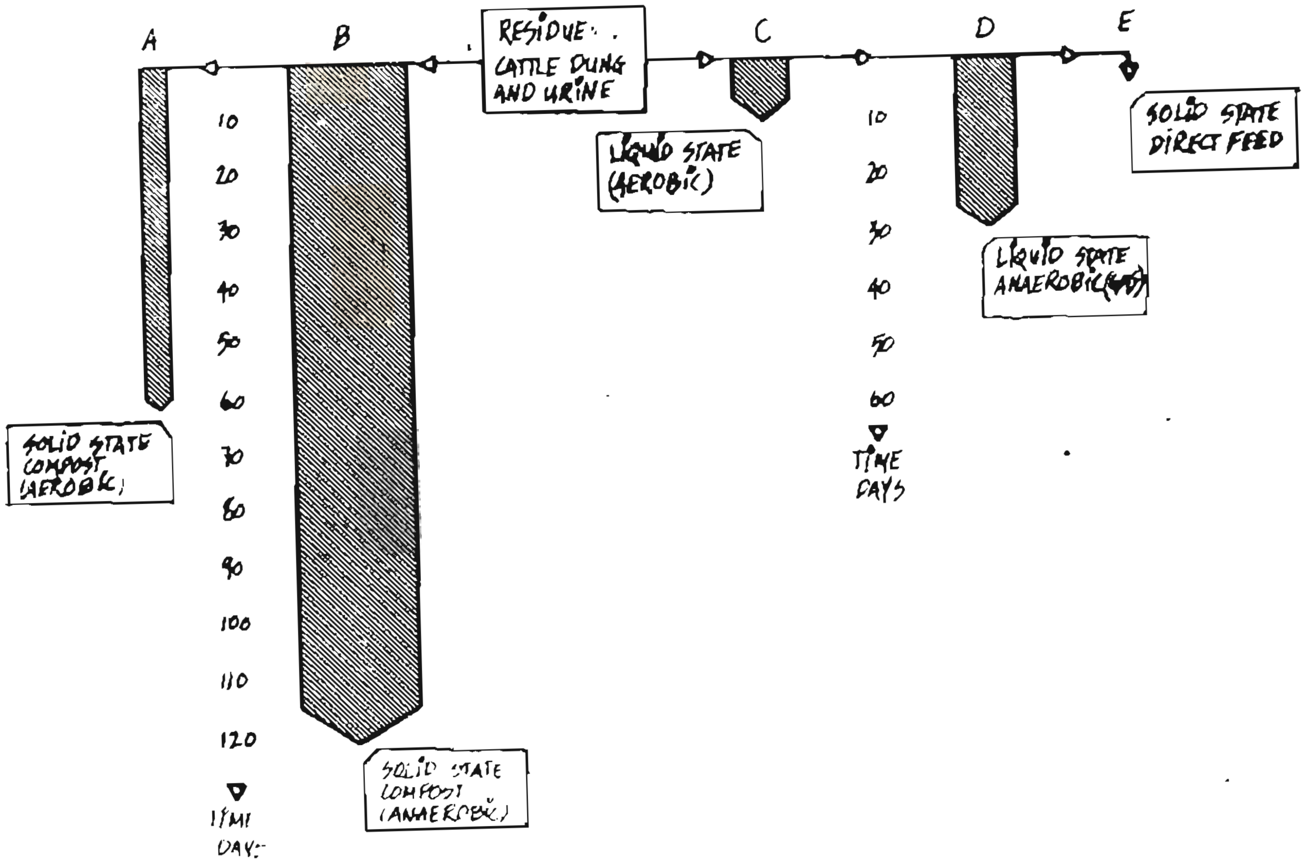
(vii) Any Alternate Marketability
(for example Packing Materials)

Slide 02 Various Present and Future Uses of Straw

And this in many ways is the crux of the problem. What are the sociopolitical and socioeconomic targets for the rural areas? It seems that unless a determined effort is made to propagate self-reliance, the increasing demands of population, industries and cities will continue to denude the rural areas even of residues, and substitute high technology items, such as kerosene, for their basic needs. However, it is true that even for strictly bioconversion modes, the choice is not obvious as to which mode is optimal and what criteria to use.

Slide 3 is a schematic of possible ways of using cattle dung (and urine). Such schematics can be visualised for other residues: even for the same residue the schematic might vary from place to place.

In looking at alternate possibilities for residue bioconversion, two parameters are of the utmost importance: a) time, and b) tradition and acceptability. The schematic in Slide 3 tries to account for these by using the width of the arrows for popularity or tradition; the broader the arrow, the more the usage of the method. In typical marginal communities, anaerobic manure piles are the rule, (process B), perhaps because of ignorance about other methods. This method of bioconversion is also the most time consuming as shown by the length of the arrow. (For other residues, the most acceptable mode might be the quickest because of the need for capital generation). Process A is very efficiently practised in China but not to a great extent in India. However it can be made popular. Process C is for, feeding the manure directly to algae/fish ponds, a process that is common in South East Asia e. g. the Philippines. It is not widely practised in India though it happens in many stagnant bodies of water naturally. Process D is the biogas process which can become widely acceptable and popular, provided the capital and technology inputs are there. Process E is almost unknown in the rural areas, though it has a great advantage in being quick. This involves drying the dung, pulverising and feeding to poultry in admixture with bran, etc. The present practice is for village chicken to grub around in dung-heaps, there being little conscious feeding.



Slide 03 Schematic for First use of Dung from Cattle in a Rural Indian Community;
(Including processes not now in use)

In the case of utilisation of dung, it can be seen that time is considered a zero-value entity: if the option on the residue were biogas generation (D), followed by A or C on the slurry, the time needed would still be very much shorter than that required for process B. Thus there is a need to evolve a system, perhaps a judicious mix of all the processes that will optimise the output to the farmer. Slide 3 was presented to emphasise the need to build-in the rate of biomass production or use along with energy usage rate. Quite often developmental efforts do not include the time parameter. An example of this is the large effort spent on cellulosic waste upgradation. Unless an alternative is available simultaneously, a waste such as bagasse will continue to be burnt in huge quantities, regardless of its potential for conversion to fodder and food.

Slide 4 presents all the variables that have to be considered for making a decision on a bioconversion mode. If the residue is seasonal, then the process should be designed with minimum idle time for any equipment. This is the kind of information that has to be put in as

input under item 1. Similarly, collection efficiency and analysis of residue have to be determined. Items 2 and 3 have to consider whether the residue is individually owned and individually used or used by the community ; also, is the desired benefit for short term capital generation so that the village can then take-off for longer-term benefits or should planning be for the long run ? Usually in the poorer Indian villages, it seems advisable to sacrifice even efficiency (if necessary) for quick capital generation, because this is what is in desperate need. In any case, it appears that technology, to stay useful in the poorest surroundings, should be highly adaptive, evolutionary and integrated.

01	Nature of Residue	Seasonal/Perennial ? Collection Efficiency ?
02	Ownership of Residue	Individual/Community
03	Desired Benefit	Capital/Fodder. Food/Energy ? Short or Long Term ? For One Man or All Men ?
04	Technology	Inputs—Advanced or Low Availability
05	Capital	Inputs—High or Low Availability
06	Labour	Skill Level ? Availability / Seasonality ?
07	Energy	Inputs—High or Low Availability
08	Land	Input, Availability
09	Delay Loop	Time for Finished Steps of Bioconversion
10	Other Factors	Possibility of Employment Generation Health & Environment Tradition Alternate Marketablility (Other than Bioconversion) Politics ?

Slide 04 Considerations used for deciding on a Bioconversion Mode

Items 4 to 8 list the main requirements of capital, energy, land, etc. in terms of input and availability. The inputs that have to be listed in such an analysis are based on process specific considerations. For example, a process such as yeast culture might involve high energy input in a low energy availability situation and therefore be considered undesirable. Items 9 and 10 are equally important. A process might have to be rejected because the residue is needed urgently for an alternate use ; therefore the time rate of utilisation and availability of the end product become paramount considerations. Also environmental factors and employment possibilities might dictate the total choice of a bioconversion mode.

Thus a proper analysis of bioconversion of organic residues needs a complete look at all possible factors and combinations. Usually the choice is not as difficult as it appears, because there is very little availability of residues that can be spared for bioconversion, except in the more prosperous villages. These however are a minority. In some areas where this Centre (MCRC) is active, the choice seems to favour that process which will lead to initial capital generation. Once capital is generated then time rate of utilisation becomes less important and one can go in for more elaborate, but more efficient designs.

To give an example of application of the factors of slide 4, the use of a residue, biogas-effluent, for three bioconversion processes leading to poultry feed or fodder is discussed next. All three processes have potential application in the rural areas, though perhaps not in the immediate future. In the next section, processcss not all leading to fodder, but for different end uses (i. e., energy and fodder) are considered and compared.

Consider the mass-culture of algae, yeast and photosynthetic bacteria on biogas effluent. Spirulina has been grown by this Centre on such effluent, unfiltered, 2-5 v/v % of the total culture, with an initial boost of 50% by weight Zarrouk's medium[2].

Harvesting of the open-air culture is on every alternate day ; drying is in solar driers. The skill level needed is high school trained workers ; other than that, no special requirements are needed. The methods, culture-ponds, etc. are reported in MCRC's Technical Notes [3]. The average yield, during the months, June to September 1978 was 10 gm/m^2/day in ponds of 30 cm depth, maximum. This was a period of unusually heavy monsoons.

As compared to the yeasts, algo-cultures are very slow yielding, especially the blue-greens. Irgens and Clarke[4] have reported the possibility of yeast culture in anaerobic digester

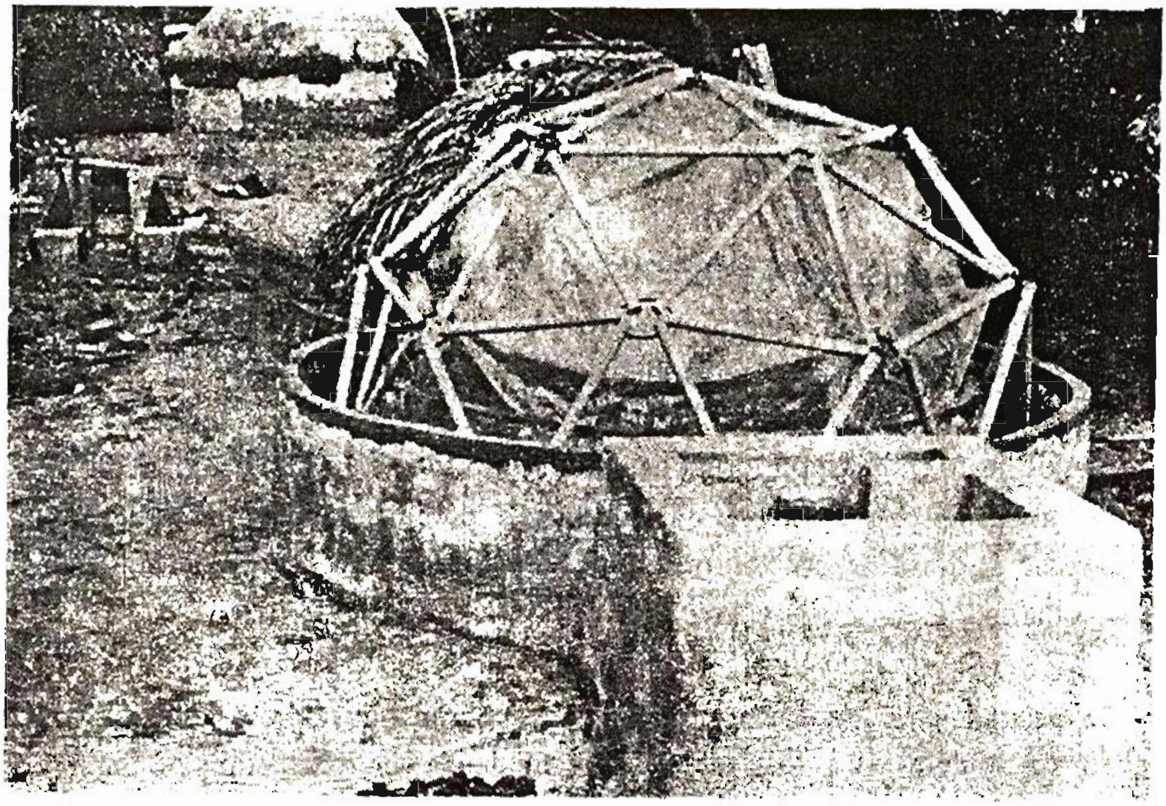
supernatant, supplemented with 1-2% carbohydrate. The energy and skill requirements are very high, especially in the harvesting cycle. Unless the yeast is fed as a slurry this process might not, in spite of its higher yields, be adaptable. However the potential for S. C. P. production at the rural level is very high because of the low land requirement, (see for example Slessers[5]), high nutrient value, (even accounting for nucleic acids content) and availability of substrate.

The situation with photosynthetic bacteria (Kobayashi[6]) is similar, except that the yield here is even higher. In this Centre, work is continuing on culturing photosynthetic bacteria on gobar-gas effluent in cheaply made, sealed, PVC bags. Harvesting the biomass is not easy, so feeding the slurry directly is the only possibility. Here the land requirement is low but the skill, energy and monitoring demands are very high. The comparison given here is an example of the choices available. The decision here would obviously be for algal cultures with yeast as a future possibility. In deciding between widely differing end products, the decision making is even more involved.

Suppose the choice is between making say, compost out of a residue, or converting it to energy, or to edible biomass (for animals or humans). In evaluation of the product, one runs up against the problem of having to compare the benefit of something that is expressed in megajoules versus something that may have an additional value (other than energy) as a protein source. The mere calorific value of a foodstuff is inadequate as a basis of comparison with other materials as far as its benefits are concerned. There is a need for a common yardstick which combines the various uses of organic residues and presents one basis for comparison. MCRC is working on this problem.

To sum up this part, a qualitative basis for evaluation of organic residues vis-a-vis their bio-conversion possibilities has been presented. The various factors that have to be considered have been discussed.

II. SOME RESULTS AND COSTS FROM INTEGRATED SYSTEMS : Slide 5 shows a system of algal ponds with a biogas system in actual operation in a village. This system has been in commission since September 1978 and is operated using local skills. The next slide, Slide 6, shows the physical data with some costs from this system. The technical details are essentially as described by MCRC[3].



Slide 5 System at Injambakkam

Slide 7 shows some actual data from a biogas effluent-fed algal pond, growing Spirulina. It appears from the 2nd column that a medium consisting of ½ Zarrouk's formula[2] plus 2 litres/day of unfiltered biogas effluent every alternate day performs satisfactorily. The culture volume was on the average 150 litres, the area exposed was 2 m^2/pond, and an initial start of 5 litres of biogas effluent was added to the culture. The harvesting every alternate day of the culture proved to yield more than if it were harvested every day. Occasionally a bicarbonate boost was given to the ponds to keep up the pH. Small amounts of HPO_2^{4-} and NO_3 were added primarily to the pure synthetic medium culture, but also occassionally to the other cultures. The other information is as given on the slide.

LOCATION : INJAMBAKKAM VILLAGE

Number	Item & Description	Cost Rs.	Depreciation Rs. (Percent/Year)	Remarks US \$ = Rs. 8.00
01	Digester MCRC Design 4/5 Cattle	878	31.00 (5)	Includes Labour Depreciation on Materials
02	Geodesic Support MCRC	322	14.60 (5)	Same as Above
03	Gas Container Transparent PVC + Coconut Thatch	175	88.00 (50)	Depreciation on Total
04	Piping & Burner Bought off the shelf	100	10.00 (10)	...
05	Algal Ponds Clay/Sand Bund Lined with 1000 G(HDPE) Exposed Area = $3 m^2 + 6 m^2 + 9 m^2$	618	257.00 (50)	Price/m^2 = 34.34 Depreciation on Materials
06	Solar Driers MCRC	100	40·00 (50)	Price/m^2 = 33.00 Depreciation on Materials
07	Buckets, Screens, Etc Bought off the shelf	50	50.00 (100)	—
		Σ = 2243 00	Σ = 440.00	

08	Interest on Borrowings 4 Percent/Year = Rs 92.00 (4 Percent Rates Available for Poorer Sections) Interest Plus Depreciation Rs 532.00 Working Days/Year 300 Average Yield 10 gms/m^2/Day or 54 Kg/Year Credits : Biogas Plus Slurry as Manure (When not used for Algae) Estimated Share of Capital Towards Algae = Rs 6.00/Kg Labour : ½ Manday/Day for Operation : Labour Component of Capital = 25 Percent

Slide 06 System at Injambakkam

Number	Date	Yield Dry Weight in Gms: Pond PC_2 (2 m²) Full Zarrouk's as Initial Dose	Yield Dry Weight in Gms: Pond PC_3 (2 m²) $\frac{1}{2}$ Zarrouk's + 5% v/v Biogas effluent as Initial Dose	Yield Dry Weight in Gms: Pond PC_4 (2 m²) $\frac{1}{4}$ Zarrouk's + 5% v/v Biogas effluent as Initial Dose	Remarks
01	1978 Sep 5th	72	110	102	HCO_3^-, NO_3^-, PO_4^- "Boost" (To Replace Carbon Uptake By Algae) :—
02	Sep 7th	60	45	35	
03	Sep 9th	50	33	47	
04	Sep 11th	20	45	52	Pond PC_2: Every 2nd Day After Harvest
05	Sep 13th	35	5	40	
06	Sep 17th	45	65	—	Pond PC_3 · Every 25th Day Plus 2 Litres Biogas Efl 2nd Day After Harvest
07	Sep 19th	50	90	75	
08	Sep 21st	47	40	65	
09	Sep 23rd	30	—	—	
10	Sep 27th	28	25	27	Pond PC_4 : Every 12th Day Plus 2 Litres of Biogas Efl. 2nd Day After Harvest
11	Sep 29th	25	33	45	
12	Oct 3rd	20	52	42	
13	Oct 5th	20	45	35	
Total		502	653	555	
Yield in gms/m²/day		8.36	10.88	9.41	
Initial Cost of Chemicals Per Kg of Algae		Rs 3.05	Rs 1.17	Rs 0.67	Based on 300 Days/Year
Cost of "Boost" Chemicals Per Kg of Algae		Rs 20.15	Rs 2.48	Rs 5.98	

Slide 07 Spirulina Growth on Biogas Effluent Yield and Other Details

The average culture temperatures varied between 27°C at 8.00 hrs. to 34°C at 10.00 hrs. The lux readings were averaged at 20 000 lux (08.00 hrs.), 80 000 lux (12.00 hrs.) and 16 000 lux (16.03) hrs.; to prevent photo-oxidation, coconut thatch covers were used for the first three days and between 11.00 hrs. and 15.00 hrs. every day. The pH ranged between 9.5 and 10.5.

Based on the data obtained here (work is continuing), some calculations are presented to comparatively evaluate different bioconversion modes. As pointed out earlier, this kind of evaluation has to remain subjective until more quantitative yardsticks are evolved.

Consider a 5 – cow family. Assume 1 year of operation.

Then assume :

1) 80% collection efficiency (Makhijani[7])
2) 10 kg. wet dung/day of 18% dry solids (Pyle[8])
3) gas yield of 0.067 m^3/kg wet dung of 65% CH_4 and 30% CO_2 (Pyle[8]), and remainder H_2O.
4) C in dung = 30% by weight of dry solids
   C/N ratio = 18. (Pyle[8])

Carbon Balance : $\underbrace{5}_{\text{cows}} \times \underbrace{10}_{\text{kg/cow}} \times \underbrace{0.18}_{\text{dry}} \times \underbrace{0.8}_{\text{collect}} \times \underbrace{365}_{\text{days}} \times \underbrace{0.30}_{\text{C/dung}} = 788$ kg C/year enters system.

Mol. wt. of gas = 24.5; (No correction made for Normal conditions)

$$\underbrace{(0.067/22.4)}_{\text{moles of gas}} \times \underbrace{365}_{\text{days}} \times \underbrace{50}_{\text{kg}} \times \underbrace{0.8}_{\text{collect}} \times (\underbrace{0.65 \times 12}_{C/CH_4} + \underbrace{0.30 \times 12}_{C/CO_2})$$

$\doteq$ 498 kg C/year leaving as biogas in 980 m^3/year

C leaving in slurry = 290 kg/year

Based on MCRC's experience, if the slurry is to be fed to algal ponds, every alternate day, then approximately 4000 lit. of culture ponds are needed. This can be accommodated in ponds of about 14m^2 of depth of about 0.3 m. The yield of algae over 300 days of pond operation can be expected to be 42 kg (at 10 gm/m^2/day). If two ponds are used, the yield is doubled by feeding each pond alternately.

If carbon is taken as 50% of the algal biomass and nitrogen as 9%, then C utilisation is 17% based on the carbon in the slurry and nitrogen utilisation is about 21%. This is for 150 days feeding of the slurry to one pond.

Slide 8 is a projected comparison of 5 modes of dung usage, without reference to cost information. It must be emphasised that where no bibliographic references are given, the data was obtained or estimated by this Centre. They have to be checked again; an attempt however has been made to be conservative.

Number	Process	Use	Energy	Food & Other Credits	Remarks
01	Sun dry (5 Days) And Burn	Fuel	52560 MJ	— Ash, CO_2	Calorific Value : 3.6 MJ/Kg Wet Makhijani[9]
02	Sun dry, Pulverize (5 Days in Open Air or ½ Day in Drier)	Poultry Feed	—	53 Kg of Meat a year —	Roughly Estimated at 2 Percent Conversion
03	Digestion Plus Algae on Slurry (∽ 40 Days)	Gas + Algae + Slurry	980 m^3 (24290 MJ)	84 Kg Dry Algae (1600 MJ) Slurry CO_2 Etc	Based on 38 MJ/m^3 NAS[10]; Energy of Algae = 4500 Kcal/kg[11]
04	Aerobic Compost (30 Days) (Use Several Pits)	Grow *Sesbania grandi flora* (Agathi)	7 Tonnes Of Bone Dry Wood (137000 MJ)	3.50 Tonnes Wood Of Fresh ash Forage, Beans, Flowers	(a) Planting 10000 Trees/Hectare (b) Farm Yard Manure Applied at the Rate of 25 Tonnes/Hectare
05	Anaerobic Compost (120 Days)	Grow *Sesbania grandi flora* (Agathi)	7 Tonnes Of Bone Dry Wood (137000 MJ)	3.50 Tonnes Wood Of Fresh ash Forage, Beans, Flowers	(c) 25 Percent of Fresh Dung in Compost (d) Yield Taken as 120 Tonnes/Ha (Difference over unfertilized) (e) Forage and Green Matter = 20 Percent (f) Calorific Value of Bone dry wood = 4650 Kcal/kg (MCRC[12]) (g) Water and Land Scaled down from 1 Hectare (h) Yield ≃ 37 gms/m^2/Day (Wet)

Slide 08 Comparison of Some Bioconversion Modes

The first three items are self-explanatory. The fourth and fifth items involve one use of dung as compost. This is to grow *Sesbania grandiflora* (agathi) trees, a leguminous high yielding tree, growing indigenously all over South India. It is used as fodder, fuel and building wood. Our experience is that 6m high trees, weighing 16 kg. each on the average, after 9–12 months, are commonly grown. However the yield given in the slide is yield over unfertilised land. T. M. Paul[13] has demonstrated the use of barren and rocky land to grow trees. If such land is used here, then the cultivation of tree crops becomes worthwhile. If land has to be paid for, then the cost goes up sharply; in fact, upto 80% of the final value of the crop can be ascribed to land value[12].

The comparison of end products of the bioconversion steps seems to favour a conventional agricultural crop until it is realised that in most villages, land and water are at a premium. However, each situation is different and the analysis here and in Part I may determine the best usage of the residues.

III. FUTURE DEVELOPMENT POSSIBILITIES: Organised bioconversion of residues seems to be most practised in the People's Republic of China[14], but it is in its infancy in other LDC's. However the possibilities are immense with conventional and newer processes. A survey of Microbiology Abstracts[15] Section 'A' revealed * at least 25 papers on processes applicable to rural residues. Thus a determined effort to work at the *rural level* on rural residues seems to be called for.

This section indicates some possibilities for bioconversion in the future. Industrial residues from industries situated near rural centres are also listed, since the waste from a medium sized industry will probably suffice for a whole community. The possibility of generating employment from use of industrial waste should also not be ignored. In the Indian context, large industrial undertakings situated near the outskirts of township and generating usable waste should be encouraged to recycle and re-use the waste instead of being allowed to pollute the neighbourhood or to resort to expensive treatment not leading to agricultural products.

Two requirements have to be met for widespread propagation of bioconversion methods: (a) cheap fermenter designs and (b) culture or inoculum banks to supply starter cultures: this is similar to the large scale effort now being launched in supplying blue-green

* List from author.

algal cultures (G. S. Venkataraman, AICPA report[16]). If these facilities are provided and this does not seem too difficult a task, then Slide 9 shows the kinds of residues that can be popularly used. This slide just gives a representative sample and is not meant to be comprehensive.

The first item of grain, millet, etc. residues (in the locally available category) is added here to reemphasise the need to optimise the existing usage by supplying starter cultures for better ensiling, or by supplying better designs of biogas digesters or fermenters. The available quantity is so vast that commensurate work seems to be called for, for urgently solving the current problems of shortages. In many parts of India, harvested straws rot because the harvest and the monsoon are concurrent. Even good drying systems to prevent deterioration (negative bioconversion?) will go a long way to alleviate the problem. In the author's opinion, providing every reasonable-sized community a 6m×6m drying platform of hard plastered mud or cement with embedded pipe flanges in a grid will help the villages dry and preserve their crop residues more effectively. The pipe-flanges are used as anchors to fix tent-driers of plastic or thatch.

RURAL RESIDUES LOCALLY AVAILABLE

01 Grain, Millet Residues, Aquatic Weeds, Etc.
02 Paddy Steep Liquor, Biogas Effluent, Other Process Liquors
03 CO_2 From Biogas
04 Prosopis, etc., Forest Residues
05 Dung, Fecal Matter
06 Illicit Liquor Process Adaptation

INDUSTRIAL AND URBAN RESIDUES

07 Carbohydrate Residues: Sago (Cassava) Waste, Molasses, Spent Wash, Cotton Dust
08 Paddy Steep Liquor, Silk Spin Liquor, Coconut Water, Areca, Turmeric Liquors, etc.
09 CO_2 From Thermal, Cement & Fertlizer Plants
10 Fish Wastes, Silk-Worm Cocoons
11 Sewage Sludge

Slide 09 Residues Locally Available & From Proximate Industries

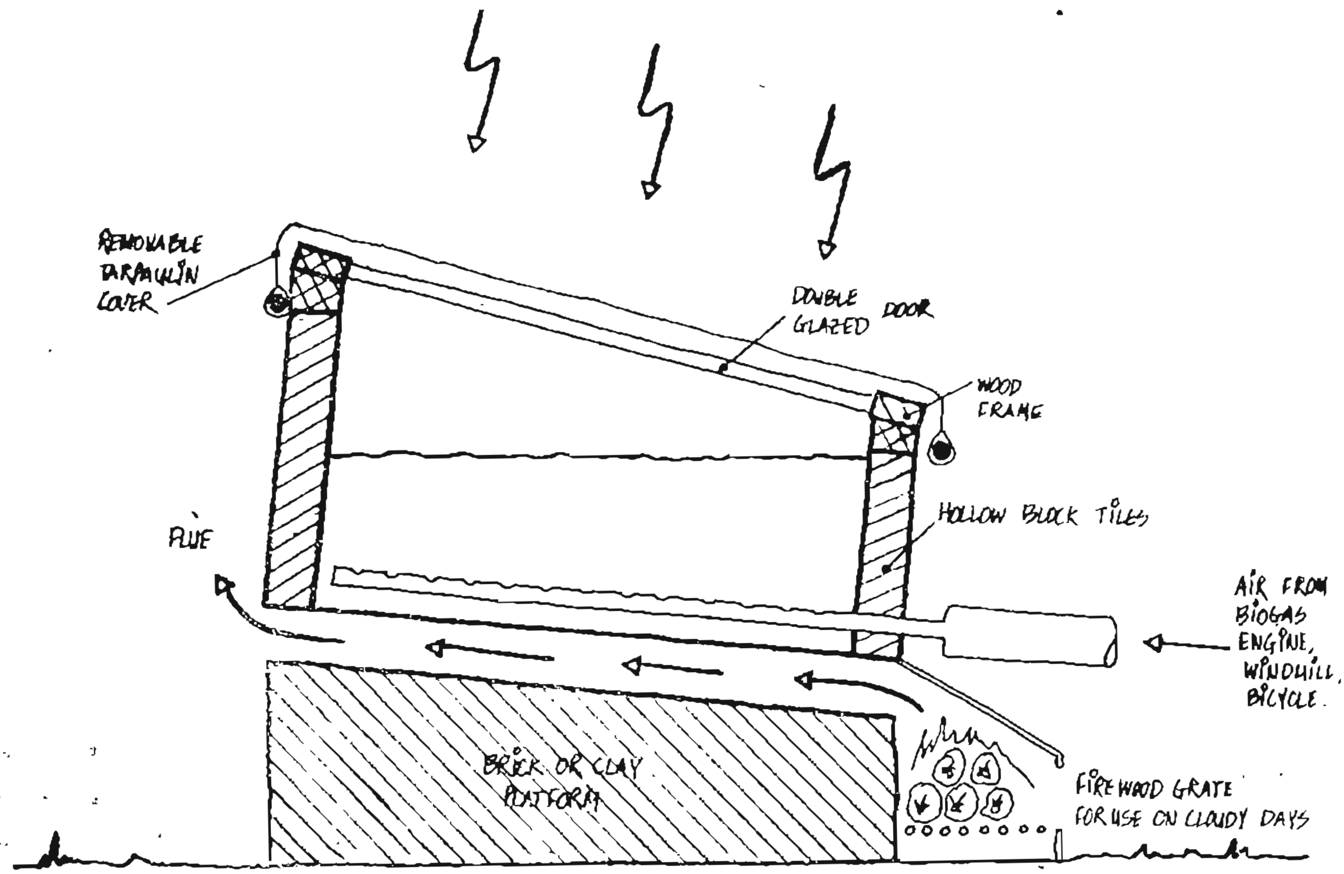
Items 2 and 8 of the Slide give some examples of the variety of process liquors now being under-utilised. Paddy steep liquor is available in millions of litres in most rice producing countries as a result of the parboiling process, and makes nutrients available for fermentation. (Bose and Ghose[17]). Similar liquors are biogas effluent (Irgens, Clarke[4]), silk liquor (conservatively estimated at about 50 millions litres per year in one district of Karnataka State alone), Coconut Water (0.5×10^6 tonnes/year), NCST[18], turmeric and areca processing liquors. All these liquors are to be supplemented by a molasses or glucose source for yeast manufacture; they supply N, P, K, and essential vitamins. Items 3 and 9 point out the need for a close look at CO_2 as a resource (MCRC—1977[19]). Both biogas as generated and combustion stack-gases are thermally valuable as well as being rich sources of CO_2 for algal cultures. Besides, the gases, being neutrally buoyant, can be transported in balloons to desired locations. Item 4 is a very valuable resource that is now only used for direct combustion. Thayer (1976)[20] has grown cytophaga on such material as fodder. Items 5 and 11 are very effectively used in China (FAO)[14] and their use should be propagated in other countries.

Item 6 refers to the fact that in India, wherever illicit liquor is brewed, it is done under conditions of very low sterility. Jaggery and acacia bark with some roots and herbs are all that are added to water and sealed in a pot and buried underground. The brew is ready to distil in 10/15 days. If the yeast can be induced to multiply under aerobic conditions, it might turn out to be a good source of protein. Item 7 refers to the need to develop valuable starch or sucrose residues as cheap substrates for indigenous fermentation. Cotton dust availability in India is 33 000 tonnes/year (NCST)[18] in a form for enzymatic degradation to glucose, or for 20–day aerobic compost. Fish wastes (item 10) can be ensiled in a remarkably simple process (Tamil Nadu Fisheries)[21]; the product is a valuable poultry ration and is stable upto 3 years. Silkworm cocoons can be dried immediately (to prevent negative bioconversion) and fed directly or ensiled by the same method as used for fish wastes.

This brief review of future possibilities for the rural communities will not be complete without a design for a cheap bio-solar fermentation device; this design is not in practice but might serve to stimulate ideas and improvement.

Slide 10 shows a box-type solar cooker (MCRC TM '77)[3] adapted for fermentation. This is made out of hollow tiles and plastered with cement with a high coefficient of thermal

expansion e.g. lime/wood-ash. The cycle that is undergone is: expose to the sun to sterilize, cover to ferment, re-expose for broth concentration. To keep up the healthy growth of aerobic organisms, a compressor driven by a bio-gas engine, or wind power or bicycle-power is used to aerate the brew. The tiles provide cellular air spaces as insulation during the sterilisation cycle. If it is cloudy, wood-fired heat can be used to sterilise the broth. Though this kind of device cannot mass produce material, it can be used to provide needed protein for children of the village.



Slide 10 Proposed Solar Fermenter, the Ravipatra.

CONCLUSIONS : This article has focussed on the factors affecting bioconversion systems at the village level in a typical Indian community. It is fairly obvious that considerations of economy of scale and many other economic criteria that would be important in

large scale industry are irrelevant where the sole goal is to improve the protein-calorie in take by a few percent and to maintain a small, albeit significant improvement in the quality of life. Bioconversion, in fact all technology, must only aim at such modest targets. To do this best the technology must be local, adaptable and evolutionary; these three qualities do not preclude sophistication of analysis or thought. This article has given some pointers.

It is a pleasure to acknowledge the enthusiastic assistance of colleagues at MCRC and correspondents all over India who have willingly sent the author material from their experience. In particular, Drs. M. S. Swaminathan, S. R. Sampath and T. K. Ghose have been of great assistance.

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